Payload prototype board test plan (version 2)

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Introduction

The payload prototype board (PPB) is an integrated high voltage power supply with two outputs suitable for biasing a single microchannel plate, and a signal processing chain with adjustable gain. During operation, the board will be sealed inside a metal enclosure (the payload prototype box) and run from a 6V battery to provide ground isolation and keep electronic interference to a minimum. This document describes how to safely test the various circuits of the PPB to verify that they are functioning correctly, and how to calibrate the dials on the board.

PPB description

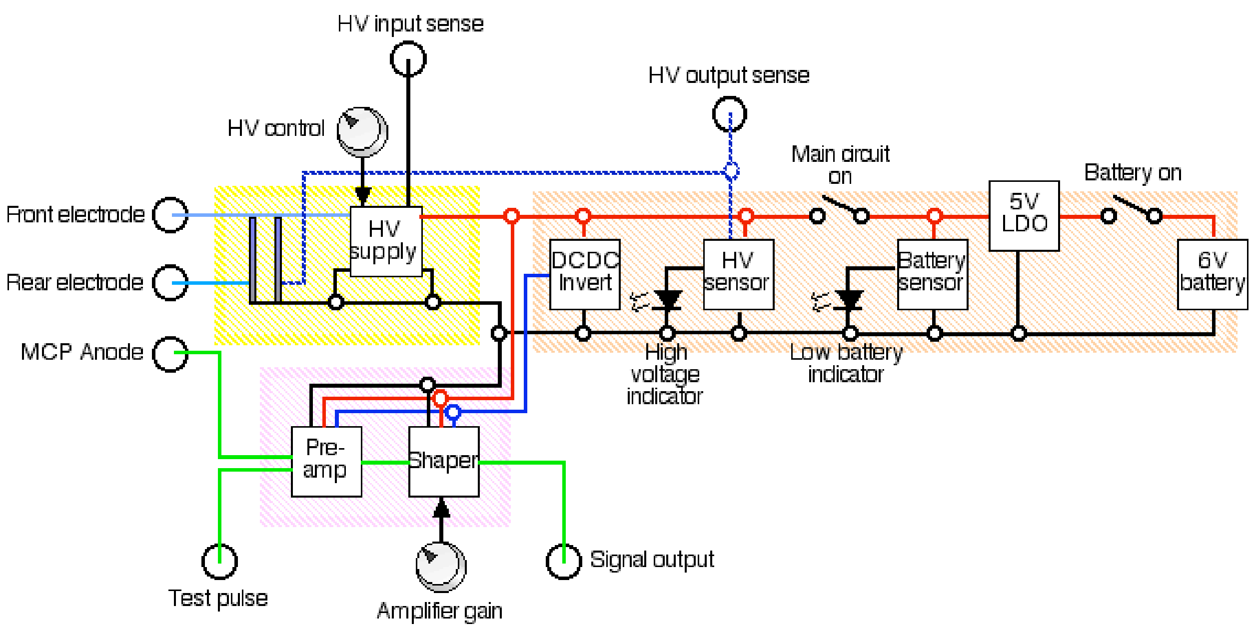

Figure 1: PPB schematic

Figure 1 shows the three main parts of the PPB:
1. The DC power supply (orange background)
2. The payload signal chain (purple background)
3. The high voltage power supply (yellow background)

Controls:
Battery switch - Turn this on to turn on the battery indicator circuit; it must be on for the rest of the unit to function.
Main circuit switch - This switch activates the high voltage supply and signal processing chain. *This switch can place a voltage of up to 1.5kV on the HV outputs. Ensure that the HV connections are secure before flipping it.*
HV control potentiometer - When this dial is turned to its lowest setting, the HV supply will be completely inactive. Above a certain cutoff point the supply will start to produce a voltage of around 200V, which is potentially dangerous.
Amplifier gain potentiometer - Sets the gain of the shaping amplifier between approximately 10 and 1000.

Inputs and outputs (connector type):

HV input sense (BNC/RG58) - This voltage on this output is equal to the voltage going into the HV supply circuit on the board, and is used for determining the circuit current drain.
HV output sense (BNC/RG58) - The voltage on this output is equal to the front electrode voltage referenced to ground, divided by 300. The rear electrode voltage is equal to 14.8% of the front voltage. It should be connected to a voltmeter.
Test pulse (BNC/RG58) - This should be connected to a tail pulse generator, and should not exceed 2V.
Signal output (BNC/RG58) - This output carries an analog voltage signal of between zero and 5V. Connect this to the multichannel analyser and an oscilloscope.
Front electrode (SHV) - Connect this to the front electrode terminal of the MCP using a high voltage cable (at least 1.5kV rated).
Rear electrode (SHV) - Connect this to the rear electrode terminal of the MCP using a high voltage cable (at least 300V rated)
MCP anode (SHV) - Connect this to the anode terminal of the MCP.

Equipment list
For the test procedures below, you will need:
2x Voltmeter with a 10V scale
1x oscilloscope with BNC connector
1x MCA with BNC connector
Cables and probes that can adapt the voltmeters and oscilloscope to both BNC/RG58 outputs and test points.
4x AA batteries with battery pack
1x current limited lab power supply
1x Single plate MCP detector body.
1x multimeter with probe.
1x plastic high voltage screwdriver
1x HV divider box

Safety
The payload prototype board (PPB) is capable of generating 1.5kV. Follow this procedure every time you use it.

NEVER operate the high voltage supply with the box open. Always run wires from outside the box to any test points, and turn the box off whenever you need to adjust any of the potentiometers.

When adjusting the HV control, use a plastic HV screwdriver to minimize the risk of shocks from the internal capacitance of the circuit.

NEVER leave the SHV connectors on the casing disconnected when the high voltage supply is active. Always either cover them or connect them to an external HV component (such as the university's HV divider box) which should itself be terminated.

When the HV warning light is on, the voltage on the HV output pins is greater than 100V. However, the warning light and the high voltage sense output will only work if the main circuit switch is on. Turn the HV potentiometer to zero and turn the circuit on, then off again.

Testing the DC power supply
Preparations:
- The internal components of the PPB are static sensitive. Take appropriate precautions.

- For testing the DC power supply, it is important to remove the sensitive and expensive signal processing chips (the A250 and A275) from their sockets in case a fault with the DC power supply fries them. These components are static sensitive and delicate. Handle them with care.

- Ensure that the HV supply potentiometer is on its lowest setting before proceeding.

- The DC power supply should be tested using a lab power pack. Connect the positive output of the pack to TP8 and the negative output to TP9.

Testing regime:
1. Checking the 5V regulator
2. Checking the indicators
3. Pumping power to the rest of the circuit for the first time.
4. Checking the noise and performance of the low voltage DC-DC converter.

1. Checking the 5V regulator
- Connect the positive output from the lab power supply to TP8.
- Connect the 0V output from the lab power supply to TP9.
- Set the current limit for the lab power supply to 30mA.
- Set the voltage for the lab power supply to 6V.
- Connect an oscilloscope to TP16, referenced to circuit ground.
- Connect a voltmeter between TP6 and ground.
- Make sure the main circuit switch is off.
- Turn on the lab power supply.
- Turn the battery switch on.
- Check the voltage reading from TP16. It should be 5V ±0.05V with less than a millivolt of noise. If it is much less than 5V and the current limit comes on, then there is a short circuit or a bad chip in the battery sensing portion of the circuit; if it is greater then the problem likely lies with the regulator. If it is zero, then check the voltage reading on TP6 - if it is 6V then the regulator may be in shutdown mode.

2. Checking the indicators
- Use the setup from above.
- Slowly turn the voltage dial down on the lab power supply. At some point before the voltage at TP6 reaches 5V, the ‘battery low’ indicator should come on. When this happens, check the voltage from TP16. It should be identical to the reading you took earlier. If it has dropped below 5V, then the resistor R21 should be replaced with one with a slightly lower value. If not, then the low battery indicator works - it warns of a depleted before the battery affects the rest of the circuit.

3. Pumping power to the rest of the circuit for the first time.
- Turn the battery switch off.
- Use the setup from above, but disconnect the oscilloscope and voltmeter.
- Make sure the HV control potentiometer is on the minimum setting, and the A250 and A275 chips have been removed from their sockets.
- Connect the front electrode connection to channel 2 of the HV divider box, and select that channel.
- Connect the rear electrode connection to channel 3 of the HV divider box.
- Set the current limiter on the lab supply to 80mA, and the voltage to 6V.
- Connect the voltmeter to between TP17 and ground.
- Connect the oscilloscope between TP18 and ground.
- Take a deep breath. Turn on the main circuit switch. Check the voltages displayed on the voltmeter and oscilloscope - they should be 5V and around -5V respectively. TP18 is unregulated and will have a voltage a little higher than 5V. Note down this voltage and the

noise characteristics on the line.
- Hopefully the HV warning light is off. If it is on, check the voltage on channel 2 of the divider box. If it is at zero, then there may be a problem with the HV indicator light. If it is above a kilovolt, then the high voltage potentiometer has been turned in the wrong direction. Turn everything off and spin it down to zero before continuing.

Testing the HV supply

Testing regime
1. Connecting up the HV supply circuit
2. Calibrating the input sensors for the HV supply circuit
3. Connecting and powering up an MCP.

1. Connecting up the HV supply circuit
- Ensure that the HV control is at zero and that all the switches are off.
- Connect the positive output from the lab power supply to TP8, and set it to 6V. Set the current limiter to 130mA.
- Connect the 0V output from the lab power supply to TP9.
- Connect the front electrode connection to channel 2 of the HV divider box, and select that channel.
- Connect the rear electrode connection to channel 3 of the HV divider box.
- Connect a voltmeter to the TP5 and another to TP4, both referenced to ground.
- Connect the oscilloscope to HV input sense on one channel and HV output sense on another referenced to ground.
- Close the PPB box.
- Turn on the battery switch.
- Turn on the main circuit switch.
- Note down the voltages on all instruments. They should all be at zero, or at most at 0.5V. Take down the current the circuit is drawing.

2. Calibrating the sensors for the HV supply circuit
- This calibration procedure is for the 'protected' configuration of the HV supply. A 12k resistor is connected in series with the HV control potentiometer that should effectively limit the voltage between the front and rear electrode connections to 1kV. This is to protect 0.5mm MCPs from voltages that could damage them. Shorting across this resistor will increase maximum plate voltage to 1.15kV, suitable for biasing 1mm thick MCPs.
- Use the previous setup, but turn off the main circuit and battery switch.
- Open the PPB box.
- Using the HV screwdriver, turn the HV control potentiometer approximately one tenth of a revolution, and measure the resistance between TP5 and ground. It should be around 10kohms.
- Close the PPB box.
- Turn on the main circuit and battery switch.
- The voltage at TP5 should be around 0.45V, as should the voltage at TP4 and the HV input sense connector. If TP4 and the HV input sense have an identical voltage different to that at TP5, but within a volt or so, then proceed. If TP4 and the HV input sense have a different voltage, then this indicates a problem with the buffer chip between the HV input sense and the rest of the circuit. Either way, note down the voltage and noise characteristics at all three points, as well as the current drawn by the entire circuit.
- The voltmeter in the HV divider box should be reading zero on both channels 2 and 3, provided the voltage at TP4 is below 0.7V. The HV output sense voltmeter should also be zero.
- Turn off the main circuit and battery switch, and open up the box.
- Turn the potentiometer another tenth of a turn.

- Measure the resistance between TP5 and ground using a multimeter. With each tenth of a turn, the resistance should increase by 10 kilo ohms.
- Close the PPB box.
- Repeat the last six steps of this procedure until the potentiometer is turned up as far as it will go. TP5 reports the voltage at the output of the potentiometer, and this should be identical to the voltage at TP4 (which is the voltage after the power transistor) and at the the HV input sense connection. When these voltages exceed 0.7V, the voltage on channel 2 of the HV divider will jump above 200V. At all times, the voltage on HV output sense should be about one three-hundredth of the voltage on channel 2. The voltage on channel 3 should be about 14.8% that of channel 2. Whatever the ratios are, note them down and ensure they remain constant as you turn the potentiometer up to its maximum setting. Also note down the circuit's current consumption at every stage.

Using the data you extract from this testing, you should be able to calibrate the outputs of the HV sense connectors to compensate for any variation in components, as well as the HV potentiometer.

3. Powering up an MCP
- The first powerup of an MCP in a newly depressurized vacuum system should be done on lab power supplies. These can be gently ramped up and the MCP can be monitored for current and resistance. Always run an MCP on lab supplies like the p6 NIM rack until it is stable at the desired plate voltage.
- Connect the positive terminal of a 6V battery pack to TP8 and the negative to TP9. You should use a battery pack with enough capacity to run the power supply for as long as the experiment lasts; performing the current measurement procedure described below will help here. Current for the whole working circuit should be below 200mA.
- Once you have a stable MCP set up and depressurized, ensure the battery and main circuit switches are off.
- Connect two voltmeters to the HV input and output sense connectors.
- Connect the signal output to a multichannel analyser and oscilloscope.
- Connect the front electrode terminal of the MCP to the front electrode connector, and the rear electrode likewise.
- Turn the potentiometer to the desired setting. Measuring the resistance between TP5 and ground using a multimeter will help set the potentiometer to the correct value.
- Check the vacuum level – below 10^{-6} millibar is the safe operating vacuum for an MCP.
- Turn on the battery circuit switch. If the low battery light comes on, stop using the PPB and replace the batteries. The circuit will *not* automatically shut down in undervoltage conditions and running it under brownout conditions probably will not do it any good, so keep an eye on the battery indicator.
- Keep your eyes on the HV output sense voltage, and turn on the main circuit switch.
- The HV output sense voltage should flick up to a value slightly below the one it had when the outputs of the supply were floating, and as the plate resistance drops it will fall further. If it is more than 1V less than the signal you expected to receive at this setting, then the plate is highly conductive which is a potential problem. If the output sense voltage is exactly the same with the MCP connected as without it, then this indicates a bad connection somewhere in the circuit. In any case, problems mandate an immediate shutdown of the PPB. You should use more versatile lab equipment to diagnose and correct MCP problems, as the PPB is poorly suited for anything except running a stable experiment.
- Watching for fluctuations and drops in the HV output sense and HV input sense is the best way to safeguard a plate when using the PPB.

Testing the signal processing chain

Testing regime
1. Inserting and testing the signal processing chain circuitry for voltage/current characteristics
2. Running test pulses through the signal chain.
3. Calibrating the signal chain

1. Inserting and testing the signal processing chain circuitry for voltage/current characteristics
- Insert the two signal processing chips in their sockets. It would be an excellent idea to get an electronics engineer to supervise - fitting them in the wrong sockets or upside down would be an expensive mistake.
- Ensure that the HV control potentiometer is at zero. Ensure that the main circuit and battery switches are off.
- Turn the gain setting potentiometer to its highest resistance setting (minimum gain). The resistance between TP3 and ground should be 111kohms, or thereabouts.
- Connect the positive output from the lab power supply to TP8, and set it to 6V. Set the current limiter of the lab supply to 130mA.
- Connect the 0V output from the lab power supply to TP9.
- Connect one channel of the oscilloscope to TP3, and the other to the signal output connector.
- Connect a tail pulse generator to the test pulse socket. Make sure it is not turned on.
- Close the PPB box.
- Turn on the battery switch
- Turn on the main circuit switch. If the current limit starts to go off and it didn’t during step 3 of the DC supply tests, then you’ve almost certainly got a problem with the signal processing chips and should turn the board off to check their connections.
- Record the current and voltage characteristics of the PPB from the lab power supply, and the noise signal at the test point input and coaxial output.

If you took note of the current drain of the PPB during the HV supply tests at various different voltages, you should be able to calculate the current drain of the entire circuit by adding the change in current drain when HV supply was powered up onto the current drain of the PPB in the configuration above. From this, you should be able to calculate how large your battery pack will need to be to run the circuit through the course of an experiment.

2. Running test pulses through the signal chain
- Use the above setup.
- Set the pulse generator to produce single pole negative pulses with a frequency of less than 100kHz. The rise time of the pulses needs to be as short as possible, but the fall time can be much longer, so long as the fall time is much shorter than the inverse of the pulse frequency. The amplitude of the pulses should be around 2mV to model the charge output from a 0.5mm plate, and around 8mV to model the charge output from a 1mm plate. Do not set the voltage higher than 2V, on pain of amplifier saturation. If you have to see the output of the pulser on the oscilloscope in order to see this voltage amplitude, then disconnect it from the PPB and connect it directly to the scope. *Never send pulses to the signal chain when it is powered down.*
- Take note of whether the two links next to the A275 (LK1 and LK2) are shorted – they should be for this exercise.
- Turn the gain setting potentiometer to its highest resistance setting (minimum gain). The resistance between TP3 and ground should be 111kohms, or thereabouts.
- With the pulser set up properly and connected, turn on the battery switch, and then the main circuit switch. Watch out for anomalous current readings at the lab supply.
- Start the pulser sending pulses. The current readings at the lab supply should not vary by much – if they break the current limit or the current drops more than 3mA towards the current readings you took with the signal processing chips removed, then there’s a problem with the signal processing circuits or the pulse generating capacitor.

- Take noise readings from the oscilloscope at both the test pulse and the output connections.
- Can you see a bipolar shaped pulse at the output connector? If not, it is possible that the output from the amp is subsumed by the noise at the output. The signal voltage at the output should be ten times the test pulse signal voltage. If you can't see the test pulse, then shut everything off and connect one channel of the oscilloscope to TP3 before powering up again as before. If you can see a test pulse in this configuration (it should be smaller by about a tenth than the input pulse, but have a very sharp rise and fall) then there could be a problem with the A275 shaping amp. If you can't see a test pulse above the noise, then there might be a problem with the A250. Try the higher gain settings as described below and see what happens.

3. Calibrating the signal chain
- Use the settings above.
- Turn on the battery and main circuit switches, and then the pulser.
- Note down the rise and fall time of the output shaped pulse, as well as its maximum positive and negative voltage, and the ratio of the output pulse to the input pulse (the output should be ten times bigger)
- Turn off the pulser.
- Turn off the main circuit and battery switches.
- Open up the PPB box and turn the gain potentiometer up by about a tenth of a turn, noting again the resistance between TP3 and ground.
- Close the PPB box and turn on the main circuit and battery switches.
- Turn on the pulser.
- Again, take the noise reading at the output connector, and measure the ratio of input pulse height to output pulse height and rise time.
- Repeat the above steps to produce a table relating the potentiometer setting (the resistance between TP3 and ground) to the voltage gain between test pulser and the output.